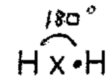
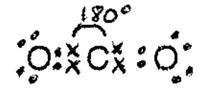
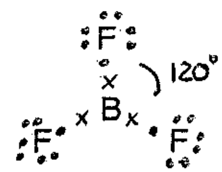
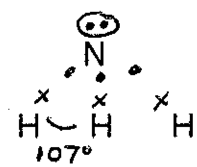
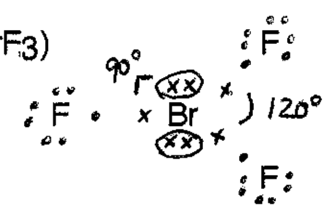
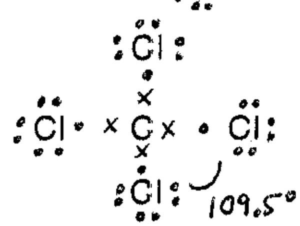
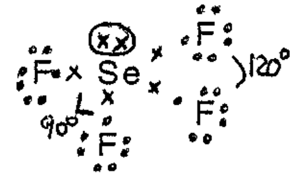
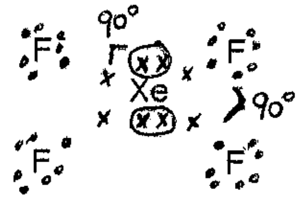
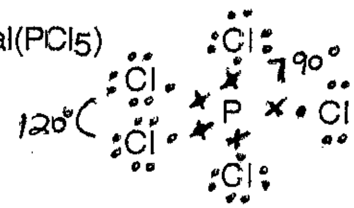
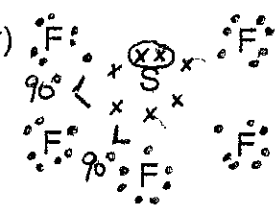
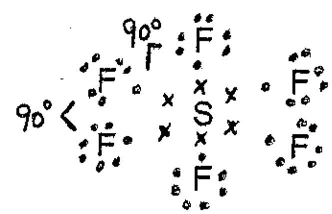
Geometry

Species	No. of Lone Pairs	Total Pair on Central Atom	Geometry	Example	Resonance	Hybridization Central Atom
AX or A_2	0	1	linear (H_2)		No	s
AX_2	0	2	linear (CO_2)		No	sp
AX_2L_y	1 or more	3 or more	bent (H_2O)		No	sp^3 for this example
AX_3	0	3	triginal planar(BF_3)		No	sp^2
AX_3L	1	4	pyramidal(NH_3)		No	sp^3
AX_3L_2	2	5	~~triginal planar~~(BrF_3) T-shaped		No	sp^3d
AX_4	0	4	tetrahedral(CCl_4)		No	sp^3

Species	No. of Lone Pairs	Total Pairs on Central Atom	Geometry	Example	Resonance Yes/No	Hybridization Central Atom
AX_4L	1	4	~~triginal bipyramidal~~ see-saw (SeF_4)		No	sp^3d
AX_4L_2	2	6	square planar(XeF_4)		No	sp^3d^2
AX_5	0	5	triginal bipyramidal(PCl_5)		No	sp^3d
AX_5L	1	6	square pyramidal(SF_5^-)		No	sp^3d^2
AX_6	0	6	octahedral(SF_6)		No	sp^3d^2

Worksheet: Geometry

Species	No. of e-'s	Lewis Dot w/Bond Angle	Bond Type	Molecule Type	Geometry	Resonance Yes/No	Hybridization Central Atom
a. H_2							
b. F_2							
c. HF							
d. H_2O							
e. NH_3							
f. CH_4							
g. Cu_2O							
h. N_2							
i. NH_4^+							
j. MnO_4^-							

Species	No. of e-'s	Lewis Dot w/Bond Angles	Bond Type	Molecule Type	Geometry	Resonance Yes/No	Hybridization Central Atom
k. Cl_2							
l. O_2							
m. HCl							
n. PI_3							
o. CCl_4							
p. H_3O^+							
q. $CrCl_3$							
r. FeO							
s. CO_3^{-2}							
t. CN^-							
u. CrO_4^{-2}							

Substance	Total # of e-'s	Lewis Dot and Bond Angles	Bond Type	Molecule Type	Geometry	Resonance (Y/N)	Hybridization on Central Atom
1. $HgCl_2$							
2. CH_4							
3. NH_3							
4. H_2O							
5. PCl_5							
6. $TeCl_4$							

Substance	Total # of e-'s	Lewis Dot and Bond Angle	Bond Type	Molecule Type	Geometry	Resonance (Y/ N)	Hybridization on Central Atom
7. ClF_3							
8. I_3^-							
9. SF_6							
10. BrF_5							
11. XeF_4							
12. HCN							

NAME......................................*PERIOD*........*DATE*............
INSTRUCTOR'S COMMENTS..

EXPERIMENT 7 COVALENT MOLECULES

PURPOSE: To construct models of molecules of covalent substances in order to show how their shapes and structure determine their polarity.

MATERIALS: Sargent Molecular Model Set or Johnglass Student Molecular Models kit.

INTRODUCTION: A covalent bond consists of a pair of shared electrons. Such a pair of electrons is shared equally between identical atoms producing a bond which is pure (non-polar) covalent. The unequal sharing of the electron pair between two different atoms produces a bond which is more or less polar. The polarity of the bond may be described in terms of its percentage of ionic character. This depends on the electronegativity difference between the two bonded atoms. The electronegativity of an atom (element) is a measure of its tendency to attract the electrons forming a bond between it and another atom.

Molecules of covalent substances may be nonpolar or polar. A diatomic molecule of an elementary gas is nonpolar. A diatomic molecule of a compound is linear (straight line) and may be polar. More complex compounds have molecules which may be polar or non-polar depending on the symmetry of the bonds to the central atom and consequently on the symmetry of the molecular structure. A molecular structure, even though its bonds are polar bonds, will be nonpolar if the bonds are arranged evenly about the central atom. When the arrangement of the polar bonds is unsymmetrical, the resultant molecule is polar and is called a dipole. Representative molecules may be bent (nonlinear) or trigonal pyramids. A dipole acts as if it has a positively charged portion and a negatively charged portion equal in magnitude of charge(s) and separated by some distance.

SUGGESTION: Consult tables of (1) electronegativities and (2) electronegativity difference and percentage of ionic character as needed: See MODERN CHEMISTRY, 1970 edition. Check the Table of Contents of your model set (pasted on the inside of the box cover) with the actual contents. At the end of the experiment, reassemble the kit into the pattern shown on the box cover. Use the long(est) set of spring connectors for multiple bonds.

PROCEDURE: Assemble the first set of seven models and have them checked by the teacher. Fill in the Data Table at the bottom of this page and at the top of the next page. Take these models apart and proceed similarly with the second set.

DATA TABLE

Formula	*Electron-dot formula*	*Bond type* (polar or nonpolar)	*Shape of molecule* (linear, bent, pyramidal, tetrahedral)	*Kind of molecule* (polar or nonpolar)
Set 1.				
a. H_2				
b. Cl_2				
c. O_2				
d. N_2				

Formula	*Electron-dot formula*	*Bond type* (polar or nonpolar)	*Shape of molecule* (linear, bent, pyramidal, tetrahedral)	*Kind of molecule* (polar or nonpolar)
e. HCl				
f. BrCl				
g. HBr				
Set 2.				
a. H_2O				
b. CO_2				
c. H_2S				
d. NH_3				
e. CH_4				
f. CCl_4				
g. CH_3Cl				

QUESTIONS

1. Calculate the electronegativity difference and percentage of ionic character for each of the following bonds:

	Electronegativity difference	Percentage of ionic character
a. H—O		
b. H—N		
c. H—Cl		
d. Br—Cl		
e. H—S		
f. H—C		
g. Cl—Cl		
h. C—O		
i. K—Br		
j. Na—O		

2. Classify each of the following as ionic crystal, polar covalent molecule, or nonpolar covalent molecule:

a. Br_2 . . . .

b. $MgCl_2$.

c. CCl_4 . .

d. HI . . . .

e. CO_2 . . .

f. H_2O . . .

g. N_2 . . . .

h. $BaBr_2$.

3. Both water and carbon dioxide are triatomic molecules. Explain why one of these is polar and the other is nonpolar. . . . .

Set 1

Formula	Electron-dot formula	Bond type (polar or nonpolar)	Shape of molecule (linear, bent, pyramidal, tetrahedral)	Kind of molecule (polar or nonpolar)
H_2				
Cl_2				
O_2				
N_2				
HCl				
BrCl				
HBr				

Set 2				
Formula	**Electron-dot formula**	**Bond type** (polar or nonpolar)	**Shape of molecule** (linear, bent, pyramidal, tetrahedral)	**Kind of molecule** (polar or nonpolar)
H_2O				
CO_2				
H_2S				
NH_3				
CH_4				
CCl_4				
CH_3Cl				

Set 1

Substance	Total # of e-'s:	Lewis Dot and Bond Angle	Bond Type:	Molecule Type	Geometry
a. H_2					
b. Cl_2					
c. O_2					
d. N_2					
e. HCl					
f. BrCl					
g. HBr					

Set 2

Substance	Total # of e-'s	Lewis Dot and	Bond Type	Molecule Type	Geometry
a. H_2O					
b. CO_2					
c. H_2S					
d. NH_3					
e. CH_4					
f. CCl_4					
g. CH_3Cl					

SHAPES AND POLARITIES OF COVALENT MOLECULES

21

The most common type of chemical bond between two atoms is a covalent bond. The covalent bond consists of a pair of shared electrons, one from each atom. If this pair of electrons is shared between two atoms of equal electronegativities, the bond is called a **nonpolar covalent bond.** However, in most cases, the pair of electrons is shared by two atoms of different electronegativities. Thus, the pair of electrons is shifted toward the more electronegative element. A partial negative charge results on one side of the bond and a partial positive charge on the other. This type of covalent bond is called **polar covalent.**

Molecules composed of covalently bonded atoms may also be polar or nonpolar. For the molecule to be polar, it must, of course, have polar bonds. But the key factor for determining the polarity of a molecule is its shape. If the polar bonds (dipoles) are symmetrical around the central atom, they offset each other and the resulting molecule is nonpolar. However, if the dipoles are not symmetrical around the central atom, the electrons will be pulled to one end of the molecule. The resulting molecule is polar.

Ball and stick models are often used to demonstrate molecular shape. In this exercise you will build several covalent molecules and predict each molecule's polarity on the basis of its molecular shape.

Objectives

In this experiment, you will

- build models of some simple molecules,
- predict each molecule's shape using your knowledge of hybridization, and
- predict each molecule's polarity on the basis of its shape.

EQUIPMENT

student set of ball and stick models

PROCEDURE

1. Prepare a data table as directed in the Analysis.
2. Build models of the following molecules. (When in doubt, have your teacher check your model.) Remember that some atoms, such as carbon and oxygen, can form multiple bonds.

H_2	CH_4
HBr	HClO
H_2O	O_2
NH_3	AlH_3
CH_3NH_2	CH_3Cl
CO_2	HCOOH
H_2CO	C_6H_6
C_2H_2	C_6H_6O (two structures)

ANALYSIS

Prepare a table for recording data on each molecule. Include in your table the formula, the Lewis dot structure, diagram of the ball and stick model, the name of the molecular shape (linear, angular (bent), tetrahedral, and so on), and the molecular polarity (polar or nonpolar) for each molecule. Use Table 21-1 as a guide.

Table 21-1

Formula	Electron Dot Structure (Lewis)	Ball & Stick Models	Shape of Molecule	Molecular Polarity
HCl	H:C̈l:	H–Cl	Linear	Polar

CONCLUSIONS

1. Explain how you were able to determine molecular polarity on the basis of molecular shape. Cite examples from your results.
2. Discuss the advantages and disadvantages of using ball and stick models as learning aids. Recommend an alternative to using the ball and stick models.

FURTHER INVESTIGATIONS

1. On the basis of this experiment and your class work, predict the (a) type of bonding, (b) molecular shape, and (c) molecular polarity for the following:

   a. HCl   c. $BaCl_2$

   b. SCl_2 d. PH_3

2. Calculate the electronegativity difference and indicate the type of bond for the following pairs.

   a. Na–Cl   c. Se–O   e. Mg–Cl

   b. C–H   d. N–N   f. Cu–Br

3. What does the term "isomer" mean? Which one of the molecular substances in this experiment forms isomers?

NAME PERIOD 4/12/02

Formula	Lewis Dot Structure	Structural	Geometry	Molecule Type
H_2				
HBr				
H_2O				
NH_3				
CH_3NH_2				
CO_2				
H_2CO				
C_2H_2				
CH_4				
HClO				
O_2				
AlH_3				
CH_3Cl				
HcCOOH				
C_6H_6				
C_6H_6O				

Formula	Electron Dot Structure (Lewis)	Structural Models	Geometry	Molecule Type